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Prediction of habitats on a fishing bank off Northern Norway using a combination of multivariate analysis and GIS classification

Pål Buhl-Mortensen, Margaret Dolan, Lene Buhl-Mortensen

EXTENDED ABSTRACT

MAREANO (Marine AREAdatabase for NOrwegian coast and sea areas) (www.MAREANO.no) is a multidisciplinary mapping programme, focusing on offshore areas in the southern Barents Sea. It was initiated to address the lack of knowledge about the seabed and environment which is required for informed, sustainable management. The mapping programme includes acquisition of multibeam bathymetry and backscatter data together with a comprehensive, integrated biological and geological sampling programme. Equipment used includes underwater video, box corer, grab, epibenthic-sled, and beam trawl. Mapping outputs from the project include bathymetric data, geological maps (morphology, hard and soft seabed, sediment grain size distribution, sedimentary environment, geological genesis), biological maps (including biodiversity and faunal distribution), and benthic habitat maps. Habitat maps are produced by combining information on landscape features, sediment types, and biological communities. The Tromsøflaket fishing bank was used as a case-study area to develop suitable habitat mapping methods. Multivariate statistical methods were used to relate bottom environment (including multiscale physical descriptors of the seabed derived from multibeam data) and faunal distribution in order to find objective criteria for definition of habitats and biotopes. Prediction of habitat distribution was performed using a supervised GIS classification using physical seabed descriptors for the faunal groups identified by correspondence analysis. The faunistic results from the bottom samples were used to describe the biodiversity of the identified habitats. For future MAREANO cruises an important task will be to ground truth habitat predictions and to test the reliability of these predictions in the wider MAREANO area.

The study area is situated on Tromsøflaket fishing bank offshore northern Norway (Fig. 1). This was the first area mapped and sampled under the MAREANO programme in 2005-2006, and provides a good area for testing and development of methodologies.

Data for this study comprises two main datasets, multibeam echosounder data and video data. In addition, results from benthic macrofauna samples represent data for description of the general biodiversity of identified habitats. The multibeam data (bathymetry and backscatter) were acquired using a Kongsberg Simrad EM1002 (95 kHz) multibeam system. These data have been processed to produce bathymetry and backscatter raster grids with a cell size of 10 m, which have been converted to ArcGIS format for use in this study.

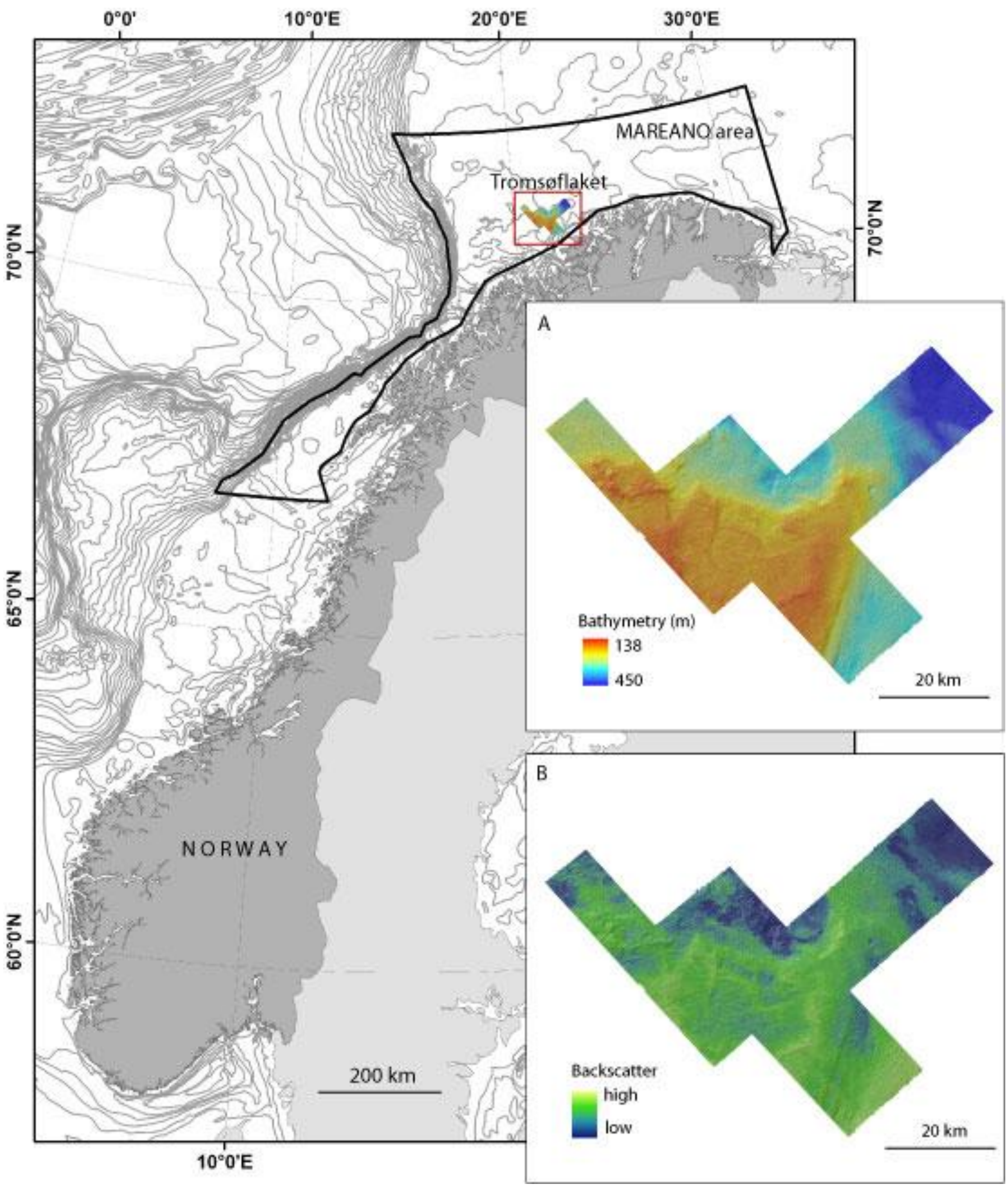

Figure 1. Overview map showing study area Tromsøflaket within MAREANO area offshore northern Norway. Inset maps (A, B) show multibeam bathymetry and backscatter data for eastern Tromsøflaket. Regional bathymetry is indicated by 100 m contours.

Video records were acquired during the first MAREANO sampling cruise in June 2006. Video was recorded with a high definition colour camera (Sony HDC-X300) tilted forward at an angle of 45 deg on the video platform 'CAMPOD'. During transects, each approximately 1 km long, CAMPOD was towed behind the survey vessel at a speed of 0.7 knot and controlled by a winch operator providing a near constant altitude of around 1.5 m above the seabed. Geo-positioning for the video data was provided by hydroacoustic positioningsystem (Simrad HIPAP and Eiva Navipac software) with a transponder mounted on the CAMPOD, giving position accurate to about 2% of the water depth. Fourty-eight video records were analyzed in detail initially using 30 second long sequences (average length = 12m). All organisms were identified to the lowest possible taxonomic level and counted, or quantified as % seabed coverage following the method as described by Mortensen and Buhl-Mortensen (2005). The percentage cover of six classes of bottom substrates (mud, sand, pebbles, cobbles, boulders and outcrops, was estimated subjectively at a scale of 5 % intervals in the same video sequences. In order to convert the analysis to a distance-based assessment of bottom attributes and fauna, the 30 s sequences were pooled into distances of 50 m, 200 m, and 1 km (whole transect). Following initial analysis it was decided that the 200 m distance segments provided the most appropriate level of data for nature-type mapping.

The general procedure for characterization and prediction of habitats:

1) Multivariate analysis of species data from bottom video-surveys to find groups of locations that are similar with respect to composition of species.

2) Identification of environmental variables (e.g. depth, surface sediment composition, topography, etc) that best explain the composition of species identified on video records.

3) Comparison of the explanatory ability of variables derived from the MBE data set and parametres collected by means of visual inspection.

4)"Supervised" GIS analysis for classification with full areal coverage.

5) Presentation of the general biodiversity of habitats based on species composition in samples collected with different bottom sampling gears.

Multibeam bathymetric data provides excellent data on bathymetry and can be used to generate quantitative variables describing the terrain. A recent summary of the variables that can be computed is provided by Wilson et al. (2007). A suite of terrain variables were derived including: slope, aspect (converted to northness and eastness – see Wilson et al. (2007)), curvature and bathymetric position index – BPI (Lundblad et al. 2006), variability or rugosity (Jenness 2004). Each variable was computed from the 10 m bathymetry grid using ArcGIS tools employing a 3x3-cell rectangular analysis window, with the exception of the broad-scale BPI which was additionally calculated using an analysis window of 49x49 cells from a 50 m bathymetry grid. In this analysis we also used the multibeam backscatter data which allow us to include some proxy to the general sediment substrate type. A similar approach, combining bathymetric and backscatter derived variables has shown promise in other studies related to habitat classification (e.g. Dartnell and Gardner 2004; Whitmire et al. 2004; Whitmire et al. 2007). Rather than simply using the values of each derived terrain parameter directly, the mean and standard deviation of each terrain variable was computed over a rectangular window of 200m. This distance was chosen to correspond with the distance over which the video data were pooled. Values for each terrain variable were extracted at points every 200 m along each video transect.

In order to identify species groupings and controlling environmental factors we applied detrended correspondence analysis (DCA), using the software PC-Ord. This methodology has several advantages over alternative approaches. The basic approach is that DCA identifies species groupings first and then assesses the correlation of the environmental variables in relation to these groups along the various axes in multidimensional space. In total 13 environmental variables were used for this analysis: depth (mean for the 200 m sequences), backscatter (mean and std), slope angle (mean and maximum), aspect (direction of slope) topographic indices (rugosity and curvature), the percentage cover of the six types of seabed substrates and frequency of trawl marks. Only species occurring in >2 of the video sequences were included. These criteria left 102 taxa and 252 video sequences for the analysis.

The groups of video sequences and their associated environmental settings which emerge from the DCA analysis represent distinct habitats across the study area. We located six groups in the DCA plot (Fig. 2). Once classified by group the location of video sequences can be displayed in ArcGIS, showing the spatial variation in habitats along the video transects. This type of map, showing classification of actual observations, represents just the first stage of nature type classification. To produce a full coverage map we require some method for classifying and predicting the habitats across the entire study area. As is common in many remote-sensing classifications, training data are used to define class signatures based on other layers of data. The three strongest correlated environmental variables derived from the MBE data (depth, backscatter and broadscaled BPI) was used signature variables for the identified groups of video sequences. These signatures are then used to predict the geographical distribution of classes across the entire study area. The geographic locations of habitat groups served as training data. The 'create signatures' function in ESRI's Spatial Analyst extension for ArcGIS was used to relate the nature-type groups to the various raster layers. At each training location (polygon) this function drills down through the GIS layers and provides a statistical summary (.gsg file) of values of the various rasters that correspond to that class (habitat group) including number of samples, means and covariance matrices. In ArcGIS this spatial classification can be done using the standard statistical technique, maximum likelihood classification. This produces a raster map for the entire study area with each cell assigned to a class from the original training data based on the multivariate properties of the predictor variables (terrain variables).

By combining multivariate analysis of species and environmental observations from video transects, with full-coverage terrain variables derived from multibeam data we have been able to identify six distinct habitats on Tromsøflaket bank (Fig. 2 & 3). Using the classified video data as a training dataset we have been able to identify the multivariate signatures on a spatial basis within GIS and use this to develop a predicted classification of the entire area. Further refinement of the habitat classification and methods will be ongoing under MAREANO, as other areas area also analysed and additional habitats encountered

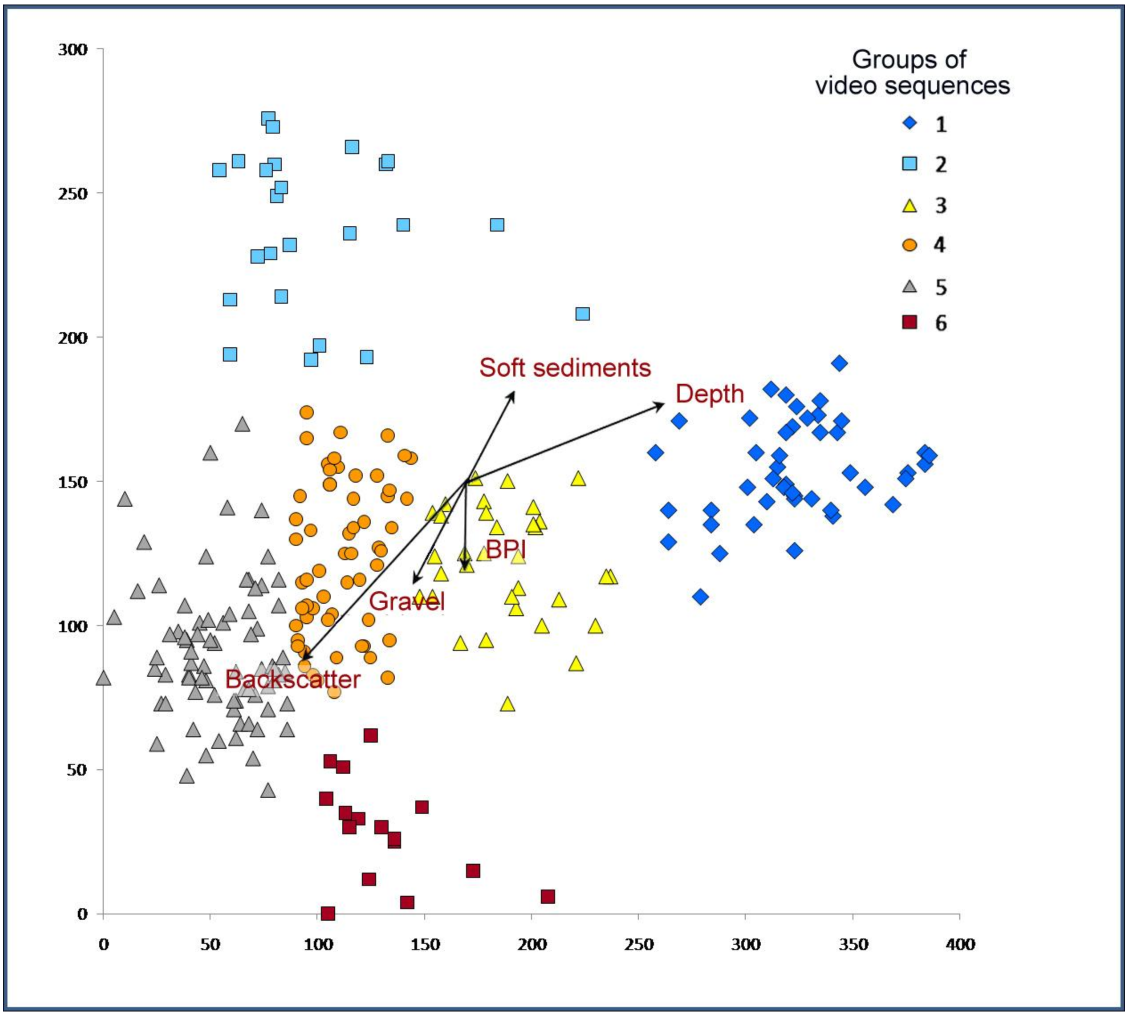

Fig. 2. DCA plot of video sequences based on species composition in 252 video sequences from 48 video transects along the seabed. The arrows indicate the relationship between the environmental variables and the ordination axes. The length of the arrows represents the strength of the correlations. BPI = bottom position index (one of the terrain indices).

Habitats on the eastern part of Tromsøflaket:

1) Deep shelf basin with fine grained mud. Typical species: *Pelosina arborescens* (Foraminifera) *and Asbestopluma pennatula* (Porifera).

2) Sandy mud at middle depths. Typical species: Various large sponges ie. *Geodia* spp.

3) Sand. Typical species: *Ceramaster granularis* (Asteroidae) and *Stichopus tremulus* (Holothuroidae).

4) Gravelly sand. Typical species: *Stylocordyla borealis* (Porifera) and *Aphrodite* sp. (Polychaeta).

5) Gravel. Typical species: *Phakellia* sp. and *Axinella* sp.

6) Morainic gravelly ridges. Typical species: *Polymastia* sp. *and Poraniomorpha* sp.

On the map (Fig. 3) of predicted habitats the groups of video sequences (Fig. 2) are located within areas with similar colours as used in the DCA plot.

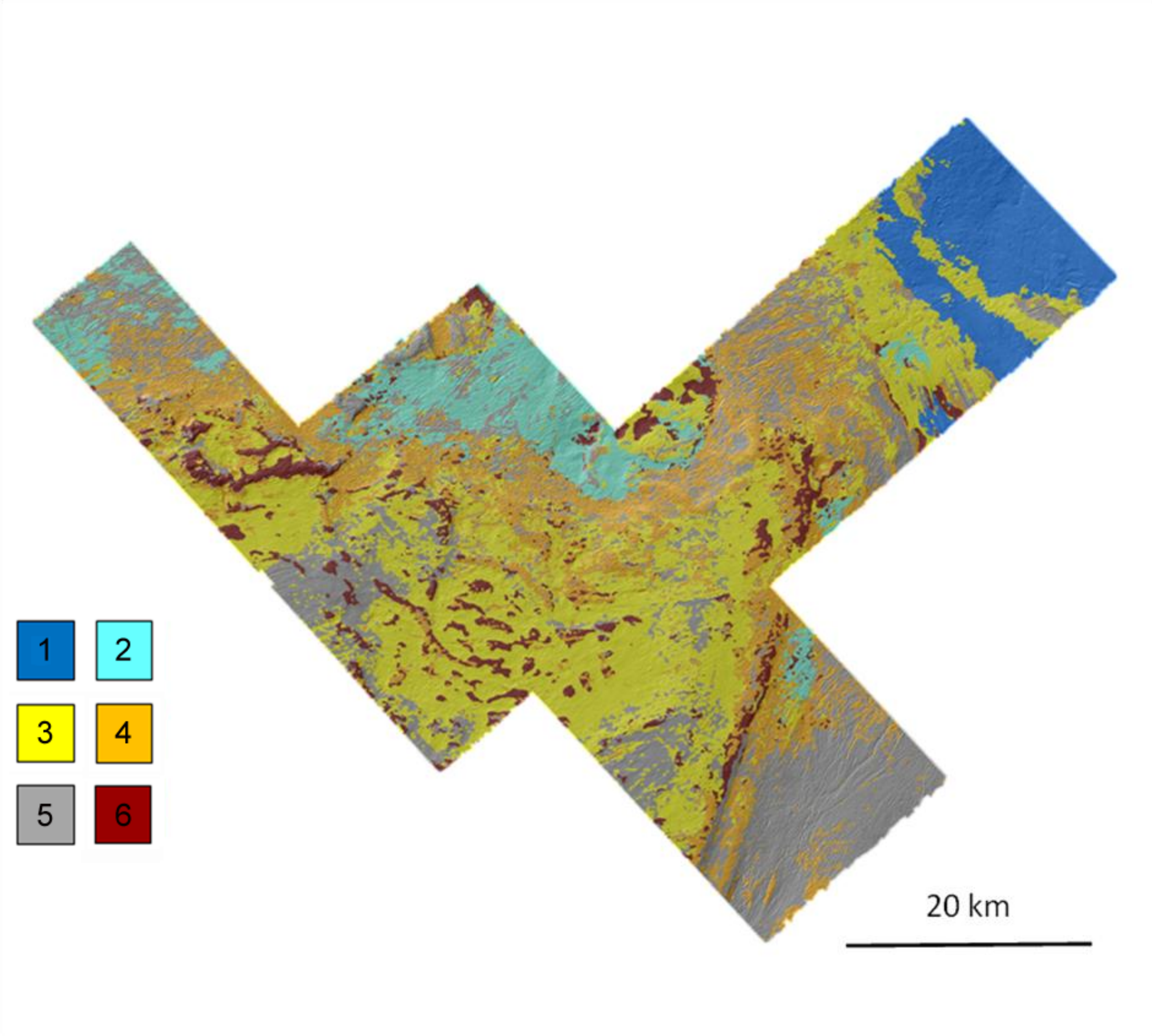

Fig 3. Provisional habitat map for eastern part of Tromsøflaket. A brief description of the six habitats are given in the text.

Species diversity of the habitats was compared between video and beamtrawl data. Except for the beamtrawl data from samples belonging to habitat 2 there was a strong correlation between average number of taxa per station or video sequence (Table 1). Group 2 was identified as the "sponge" habitat and many of the smaller organisms associated with sponges were not identified on the video records. The rest of the groups showed a similar pattern for the two methods with increasing biodiversity related to increasing cover of hard bottom.

Table 1. Comparison of diversity of taxa in habitat groups between results from video and beamtrawl.

	Video			Beamtrawl		
Group	n	Sum taxa	Average taxa	n	Sum taxa	Average taxa
1	7	43	11	3	52	24
2	4	60	35	2	164	**82**
3	6	53	20	2	48	30
4	12	86	33	6	214	36
5	14	92	**47**	8	189	54
6	5	60	4	2	72	45

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Contact author Pål Buhl-Mortensen: Institute of Marine Research, 5817, Norway [tel: +47 55 236815, fax + 4755 236830], e-mail: paalbu@imr.no